



## Limited Evaluation of AIM-9 Control Surface Effects on F-16 LCO Characteristics

Maj Anthony P. Massett  
Test Pilot

Maj Reinald G. Groult  
Test Pilot

Maj Robert T. Ungerman  
Test Pilot

Capt Jason B. Honabarger  
Flight Test Engineer

Capt Jared E. Salk  
Flight Test Engineer

1Lt Pierluigi De Paolis  
Flight Test Engineer

Lt Col Timothy R. Jorris  
Advisor

AIR FORCE FLIGHT TEST CENTER  
EDWARDS AFB, CA

August 2011

Approved for public release A: distribution is unlimited.

AIR FORCE FLIGHT TEST CENTER  
EDWARDS AIR FORCE BASE, CALIFORNIA  
AIR FORCE MATERIEL COMMAND  
UNITED STATES AIR FORCE

A  
F  
F  
T  
C

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. <b>PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.</b>					
1. REPORT DATE (DD-MM-YYYY) 03-08-2011		2. REPORT TYPE Public Release		3. DATES COVERED (From - To) Sep 2010 – May 2011	
4. TITLE AND SUBTITLE Limited Evaluation of AIM-9 Control Surface Effects on F-16 LCO Characteristics				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) <b>Anthony P. Massett, Reinald G. Groult, Robert T. Ungerman, Jason B. Honabarger, Jared E. Salk, Pierluigi De Paolis, Timothy R. Jorris</b>				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) AND ADDRESS(ES) United States Air Force (USAF) Test Pilot School (TPS) 220 S Wolfe Ave, Bldg 1220 Edwards AFB CA 93524-6485				8. PERFORMING ORGANIZATION REPORT NUMBER AFFTC-PA-1110	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force SEEK EAGLE Office (AFSEO) 46 SK/SKP 205 West D Ave, Ste 348 Eglin AFB FL 32542				10. SPONSOR/MONITOR'S ACRONYM(S) N/A	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release A: distribution is unlimited.					
13. SUPPLEMENTARY NOTES CA: Air Force Flight Test Center Edwards AFB CA                      CC: 012100					
14. ABSTRACT Limit Cycle Oscillation (LCO) is a self-sustained airframe structural response due to interaction between airframe aeroelastic properties and flight condition aerodynamic effects. F-16 LCO has typically resulted in lateral motions of the fuselage and crew that could have operational impacts on such things as pilot fatigue, weapons tracking or structural integrity. Historic flight test data could not isolate the effect that aerodynamic differences had on LCO over mass and inertia differences. This test observed and compared LCO characteristics (onset, frequency and amplitude) for an F 16D with common store loadouts, varying only AIM-9 aerodynamic properties while keeping mass and inertia properties fixed. The AIM-9 missiles used for testing were capable of having all control surfaces removed, and are denoted as dummy AIM-9s. When control surfaces were removed, ballast was added to the dummy AIM-9 bodies to match the mass and inertia properties of the dummy AIM-9s with the control surfaces attached (referred to as fins on). The general objective was to observe and compare F-16 LCO characteristics between store loadouts with dummy AIM-9 fins on and fins off. Of interest were minimum Mach for LCO at 1g, LCO wingtip acceleration amplitude and LCO frequency. A quantifiable difference in minimum LCO Mach number and LCO wingtip acceleration amplitude was found between fins on and fins off configurations. There was no consistent trend in minimum LCO onset between the two configurations. Fins configuration did not appear to have an effect on LCO frequency. From statistical analysis, the significant main factors affecting the LCO response were ambient static pressure, Mach, wing fuel, fins configuration and normal acceleration. The results from this testing will ultimately contribute to enhancing aircrew safety and mission effectiveness. Additionally, the data and statistical analysis will aid in updating current aerodynamic models in order to better understand, and more accurately predict, LCO.					
15. SUBJECT TERMS LCO, F-16					
16. SECURITY CLASSIFICATION OF: Unclassified			17. LIMITATION OF ABSTRACT  None	18. NUMBER OF PAGES  13	19a. NAME OF RESPONSIBLE PERSON 412 TENG/EN (Tech Pubs)
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified			19b. TELEPHONE NUMBER (include area code) 661-277-8615



# Air Force Flight Test Center



*War-Winning Capabilities ... On Time, On Cost*



## LCO on the F-16

**Capt Jason Honabarger**  
**USAF TPS**  
**(661) 275-9594**

Approved for public release; distribution is unlimited.  
AFFTC-PA No. 11110

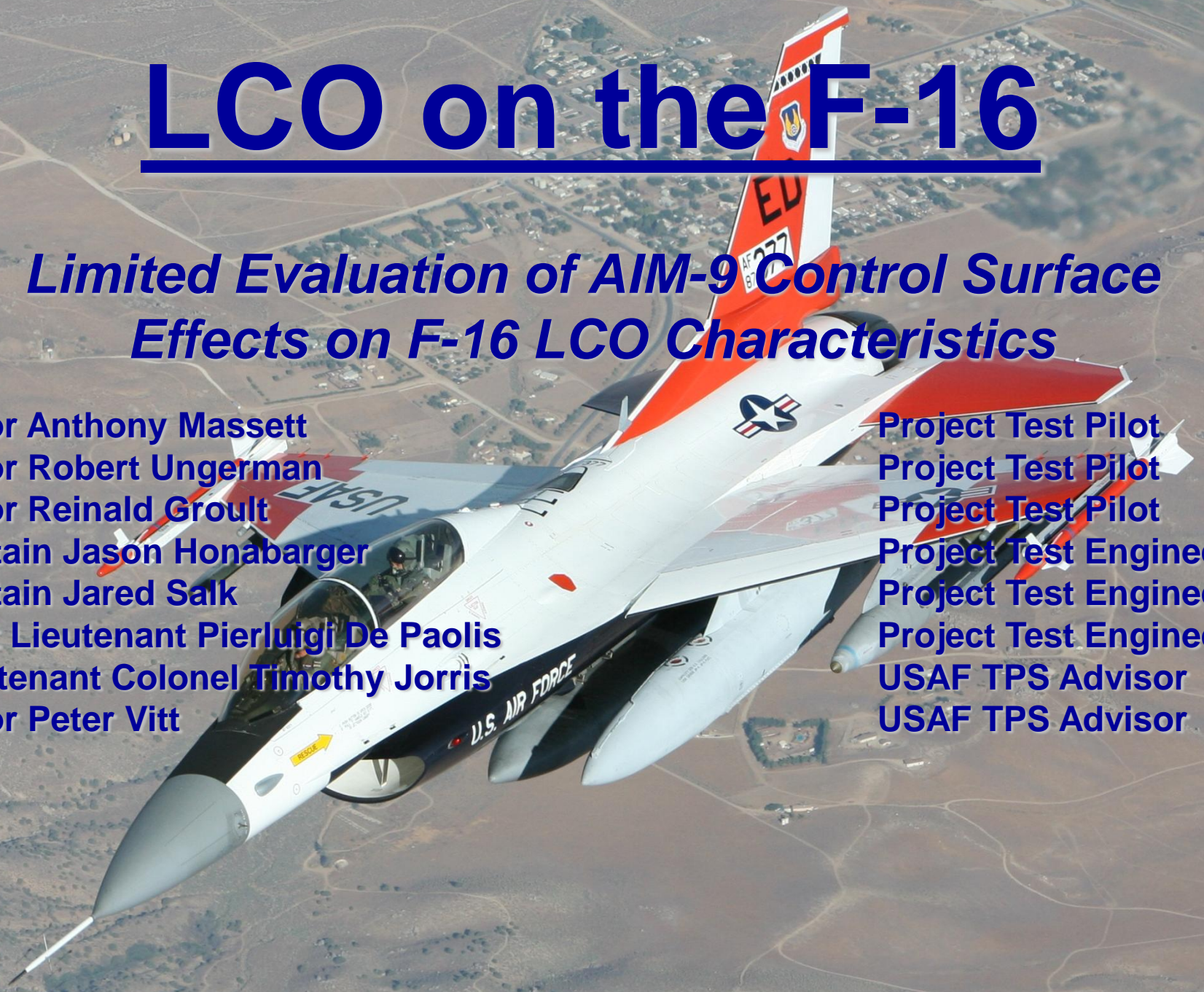
*Integrity - Service - Excellence*

# LCO on the F-16

## *Limited Evaluation of AIM-9 Control Surface Effects on F-16 LCO Characteristics*

Major Anthony Massett  
Major Robert Ungerman  
Major Reinald Groult  
Captain Jason Honabarger  
Captain Jared Salk  
First Lieutenant Pierluigi De Paolis  
Lieutenant Colonel Timothy Jorris  
Major Peter Vitt

Project Test Pilot  
Project Test Pilot  
Project Test Pilot  
Project Test Engineer  
Project Test Engineer  
Project Test Engineer  
USAF TPS Advisor  
USAF TPS Advisor





# LCO on the F-16

## Overview



- Introduction
- Test Objectives
- Findings
- Statistical Analysis
- Conclusions





# LCO on the F-16

## Introduction

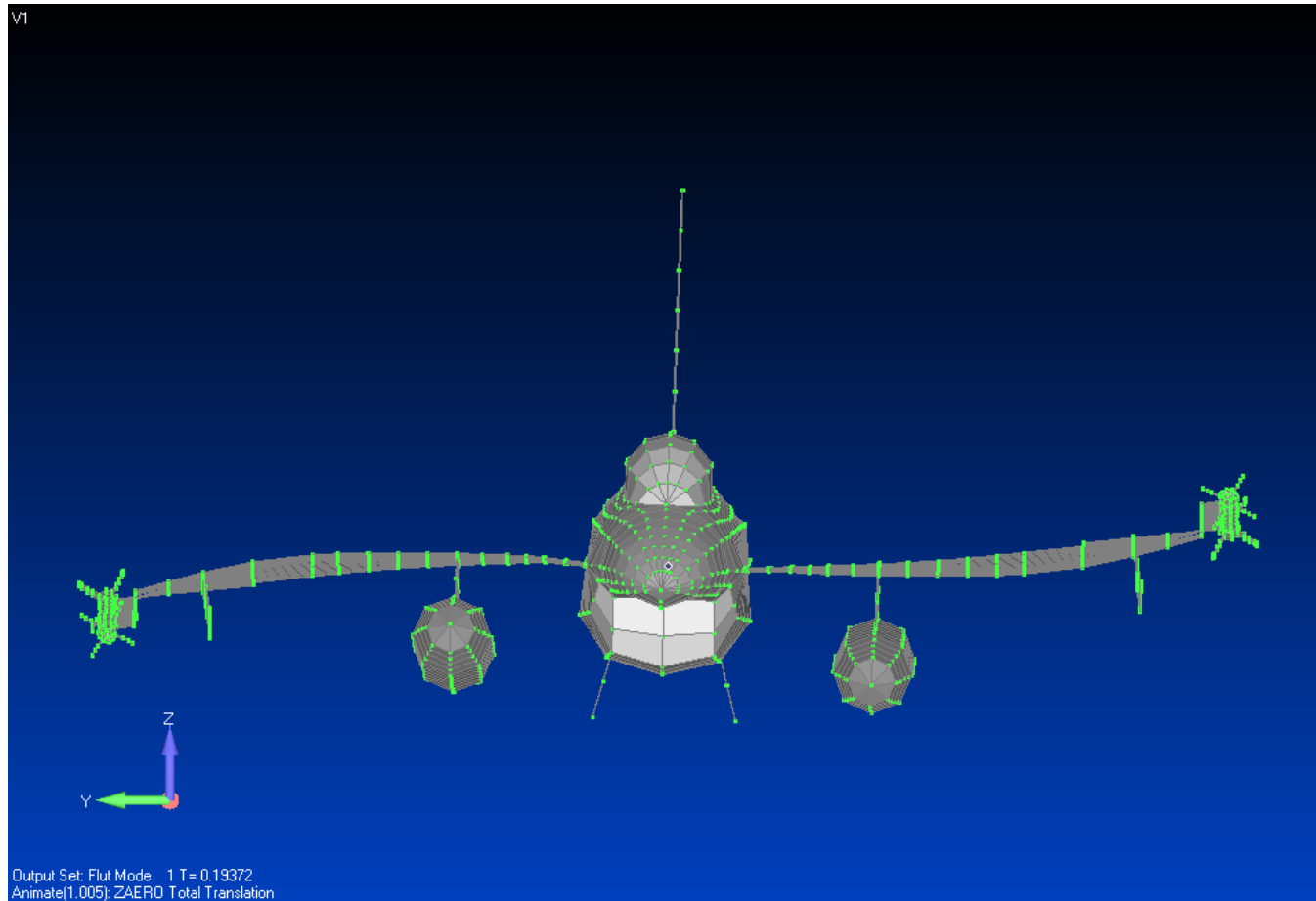


- **F-16 Limit Cycle Oscillation (LCO)**
  - Thin wings & external stores
  - Common for certain store loadouts
- **LCO operational impacts**
  - Pilot fatigue & workload
  - Weapons lock on & separation
  - Structural issues



# LCO on the F-16

## Introduction



- F-16 Zaero LCO Analysis

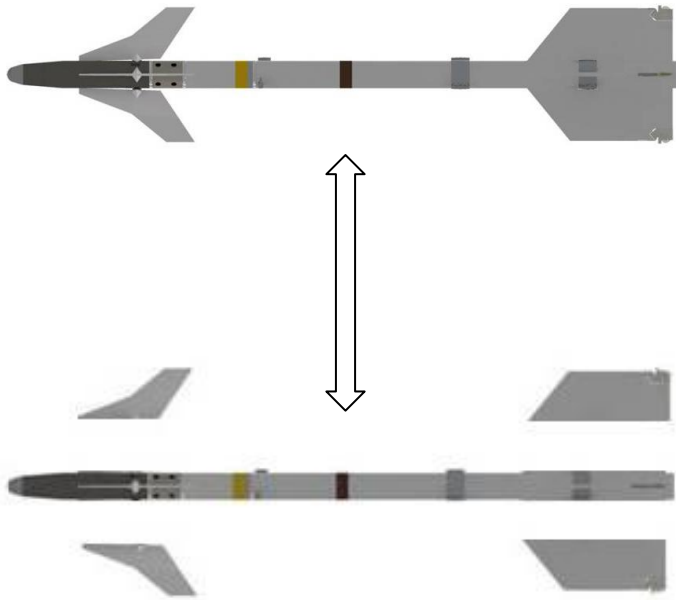


# LCO on the F-16

## General Test Objective



- Compare the LCO characteristics of common F-16 store loadouts, varying only AIM-9 aerodynamics





# LCO on the F-16

## Specific Objective 1



- **Observe LCO characteristics in test configurations with dummy AIM-9 control surfaces on and control surfaces off**
  - Minimum LCO Mach Number
  - Wingtip Acceleration (LCO Amplitude)
  - LCO Frequency

**OBJECTIVE MET**



# LCO on the F-16

## Specific Objective 2



- **Compare LCO characteristics in test configurations with dummy AIM-9 control surfaces on and control surfaces off**
  - Minimum LCO Mach Number
  - Wingtip Acceleration (LCO Amplitude)
  - LCO Frequency

**OBJECTIVE MET**



# LCO on the F-16

## Findings



- **Overall Findings:**
  - **YES – Control surfaces do matter**
  - **A quantifiable difference in minimum LCO Mach, and amplitude between fins on/off configurations was found**
  - **No quantifiable difference was found in frequency, however fins configuration was statistically determined to be a main factor**



# LCO on the F-16

## Conclusion



### Bottom Line:

***AIM-9 Control Surfaces DO Have an Effect on F-16 LCO Characteristics***



**Questions?**